Plant macrofossils from the Edgehills Sandstone, Forest of Dean

C. J. Cleal

Geological Conservation Review Unit, Nature Conservancy Council, Pearl House, Bartholomew Street, Newbury, Berkshire RG14 5LS.

Synopsis

The plant macrofossils in the Edgehills Sandstone (Carboniferous) represent a restricted 'flöznahe'-type flora, dominated by the equisete *Archaeocalamites radiatus* (Brongniart) and the lycopods *Tomiodendron variabilis* (Lele & Walton) and *Lepidostrobophyllum lanceolatum* (Lindley & Hutton). These species indicate that the Edgehills Sandstone is upper Viséan, rather than lower Westphalian as suggested on palynological evidence. It supports the view that from the late Viséan to the late Westphalian, the Forest of Dean was part of an area of non-deposition separating south Wales from the other sedimentary basins immediately south of St George's Land.

Introduction

Edgehills Quarry, near Mitcheldean, Forest of Dean (Grid Ref. SO 661168) exposes about 40 m of steeply dipping Carboniferous strata. Mostly, they are conglomerates and sandstones typical of the Drybrook Sandstone (Viséan), but the uppermost 5 m consists of rather fine sediments with a thin coal (the Edgehills Coal). Field observations suggest that these finer sediments are perfectly conformable with the Drybrook Sandstone (see Fig. 2) and a Viséan age would be assumed. However, spore floras reported from the coal seem to indicate an early Westphalian A age (Sullivan 1964, Spinner 1984). The only other palaeontological evidence available is a macroflora from the mudstone immediately underlying the coal. This is of limited composition but is sufficient to indicate an early Carboniferous (Mississippian) age. Since the age of the Edgehills Sandstone has a bearing on the general geological development of this part of Britain, a brief description of the macroflora is given here.

When Sullivan and Spinner collected their samples, there were two small quarries at Edgehills. Since then, the excavated area has been enlarged to form a single quarry. It is therefore important to justify the assumption that the macroflora came from the same level as the microflora. Fig. 3 is a map showing the positions of the old quarries relative to the new quarry, based on an old 1 : 10 560 and a new 1 : 10 000 Ordnance Survey map. According to Sullivan, the spores came from the more westerly of the two quarries, which must have shown a strike section along the Edgehills Sandstone. The position from where the macroflora was collected is marked on the map by a spot, and can be seen to be almost exactly along strike from the spore locality. The section now visible through the Edgehills Sandstone is summarized in Fig. 16, p. 242 (measured by the present author in 1983), and provides a striking similarity to the section as measured by Sullivan. The only noticeable discrepancy is the absence of the mudstone from immediately below the coal in Sullivan's section. However, it is characteristic of the Lower Carboniferous of the Forest of Dean for the mudstones to be lenticular, and so it is not surprising to find this one absent in the more northerly outcrop. In my view, all the field evidence points to the macro- and microflora having originated from the same interval of strata.

The macroflora was found in the bed of *c.* 70 cm of pale purple-grey mudstone immediately below the Edgehills Coal. The fossils are preserved as impressions, sometimes with a thin covering of sooty coal which is easily brushed off. Both the lithology of the matrix and the preservation of the fossils bear a striking resemblance to that seen in the classic Drybrook Sandstone flora found at Puddlebrook Quarry (Lele & Walton 1962).

Bull. Br. Mus. nat. Hist. (Geol.) **40** (5): 235–246 Issued 18 December 1986

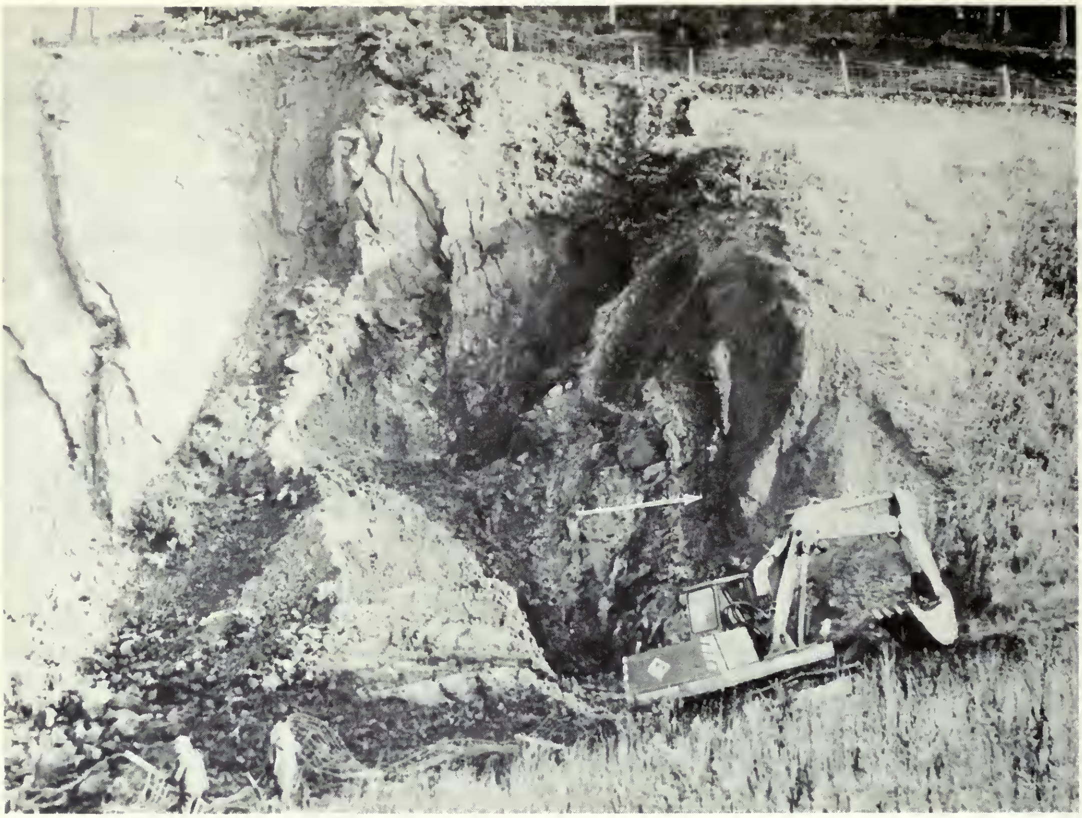


Fig. 1 Edgehills Quarry, during excavations made in 1971. Plant bed marked by arrow.

All the specimens collected by the author from Edgehills have been presented to the British Museum (Natural History) palaeobotany section. The figured material has register numbers in the range V.61742–56.

Systematic descriptions

Division SPHENOPHYTA

Order EQUISETALES

Form-genus *ARCHAEOCALAMITES* Stur, 1875

Archaeocalamites radiatus (Brongniart) Stur
Figs 4–10

1820 (?) *Calamites scrobiculatus* Schlotheim: 402; pl. 20, fig. 4.
1828 *Calamites radiatus* Brongniart: 122; pl. 26, figs 1–2.
1862 *Calamites* (*Asterocalamites*) *radiatus* Brongniart; Schimper: 321; pl. 1.
1875 *Archaeocalamites radiatus* (Brongniart) Stur: 2; pl. 1, figs 3–8; pls 2–4; pl. 5, figs 1–2.
1879 *Asterocalamites scrobiculatus* (Schlotheim) Zeiller: 17; pl. 159, fig. 2.
1964 *Archaeocalamites radiatus* (Brongniart); Crookall: 611; pl. 110, figs 1–4 (q.v. for synonymy).

Description. Numerous fragments of pith cast were found, which are up to 107 mm long and 32 mm wide. Only one has more than one node visible, and this has internode distances of 21 mm, 22 mm and 25 mm. More of less circular branch scars *c.* 5 mm in diameter are present on or near some nodes (Fig. 6), but no regular pattern of distribution is evident. Longitudinal

Fig. 2 Plant bed at Edgehills Quarry, marked by position of hammer. The thin Edgehills Coal (marked by arrow) can be seen just above the plant bed.

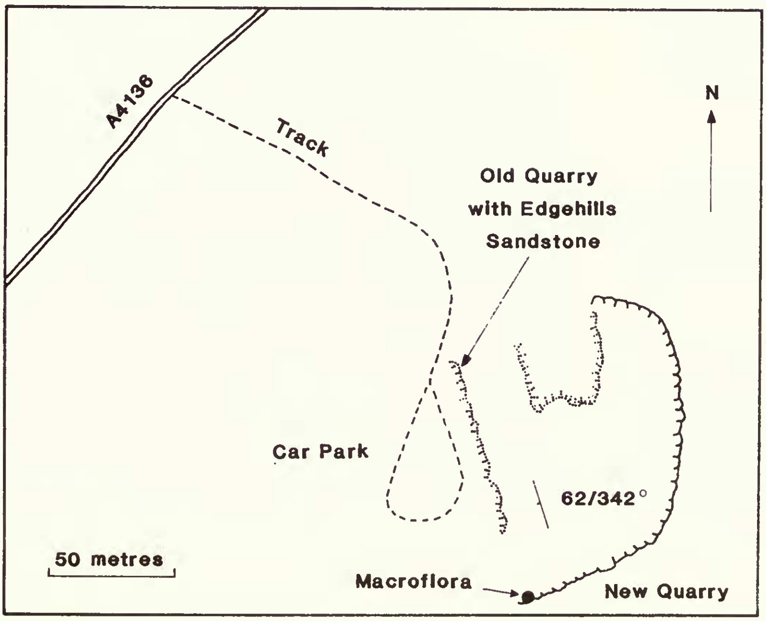
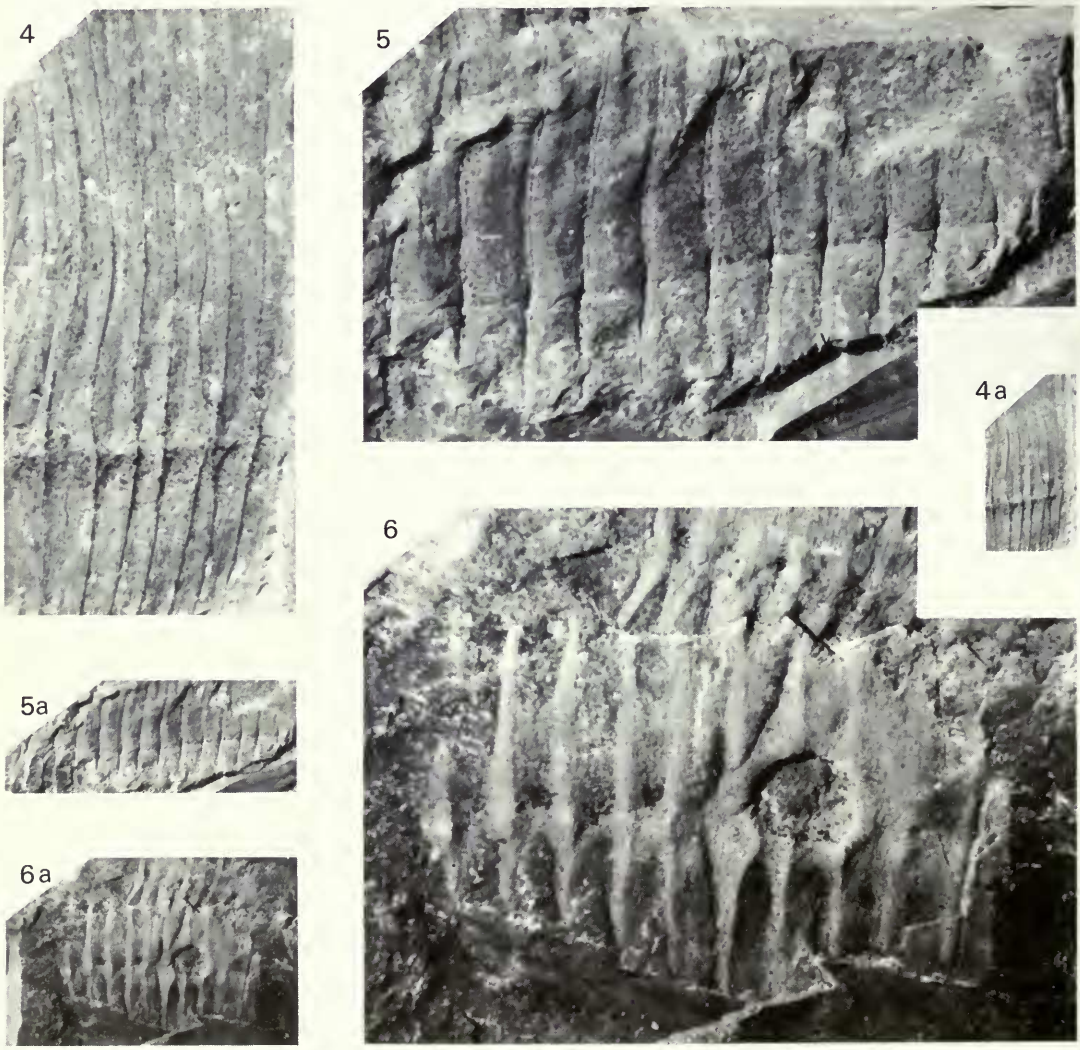


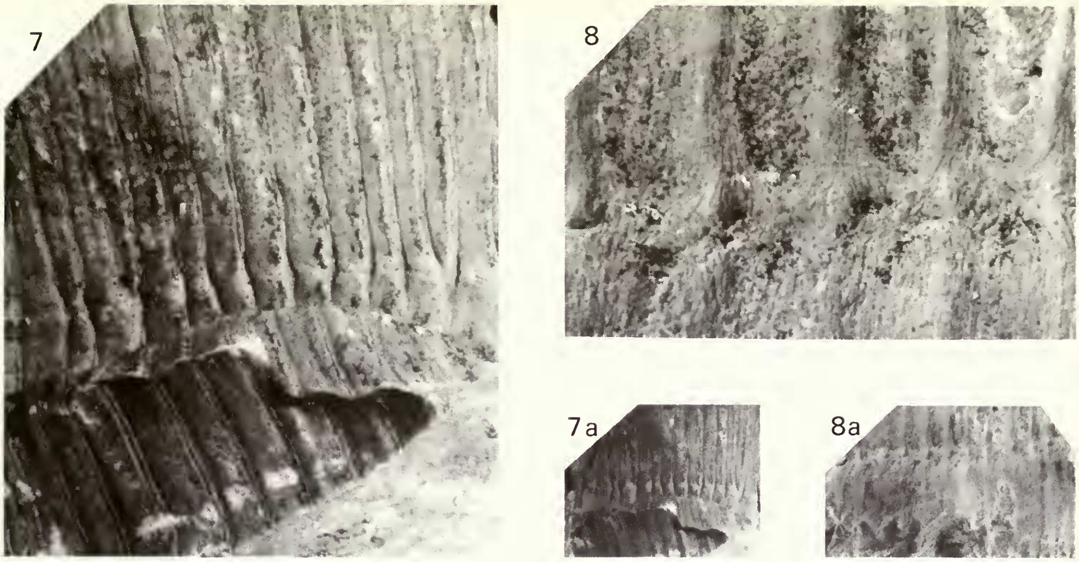
Fig. 3 Sketch map of the Edgehills area, showing positions of the old (dotted lines) and new (solid line) quarries, and the prevailing strike of the beds here. This clearly shows the relationship between Sullivan's spore locality and where the plants described in this paper were found.

ribs along the pith casts are up to 2·8 mm wide. Of the 152 ribs seen passing over a node, only 10 (6·6%) alternate (e.g. Figs 4, 7), the rest going straight over (e.g. Figs 5, 6). Two nodal diaphragms were found, both oval in shape, with average diameters of 71 mm and 34 mm (Figs 9, 10). The larger specimen shows a fine reticulation on the diaphragm, probably the impression of parenchyma cells. The diaphragm is surrounded by a stellate corona of thinner tissue, 2–3 mm wide, which is probably the splayed-out remains of the inner surface of the stem cylinder. Small oval holes occur in this tissue, *c.* 1 mm from the diaphragm. These are probably linked with leaf attachment, although no evidence of the leaves themselves was found.

REMARKS. All the specimens of *A. radiatus* (Brongniart) found at Edgehills are fragmentary, but they clearly show the characteristic non-alternating rib pattern. Some species of *Calamites* (sect. *Mesocalamites*) have a fairly high proportion of non-alternating ribs, but never more than 90% as seen here. The nomenclatural problems surrounding this species have been discussed by



Figs 4–6 *Archaeocalamites radiatus*. Figs 4, 4a, stem showing occasional alternating ribs at node, V.61742. Figs 5, 5a, typical stem showing exclusively non-alternating ribs at node, V.61743. Figs 6, 6a, stem with branch scar at node, V.61744. Figs 4, 5, 6, × 3. Figs 4a, 5a, 6a, × 1.



Figs 7–8 *Archaeocalamites radiatus.* Figs 7, 7a, stem showing mixture of alternating and non-alternating ribs at node, V.61745. Figs 8, 8a, larger stem showing close-up of rib–node interaction, V.61746. Figs 7, 8, × 3. Figs 7a, 8a, × 1.

Leistikow (1959), who has shown that *Archaeocalamites radiatus* (Brongniart) is the valid name, despite *Asterocalamites scrobiculatus* (Schlotheim) having been first published earlier.

There is only one previous record of *Archaeocalamites* nodal diaphragm compressions, based on specimens from Karl-Marx-Stadt in the German Democratic Republic (Hartung 1938). The German material shows no evidence of the cellular detail seen in the Edgehills specimens, although they do have attached leaves. Permineralized nodal diaphragms have been described from Loch Humphrey Burn in Scotland (Walton 1949).

Division **LYCOPHYTA**

Order **LEPIDODENDRALES**

Form-genus ***LEPIDOSTROBOPHYLLUM*** Hirmer, 1927

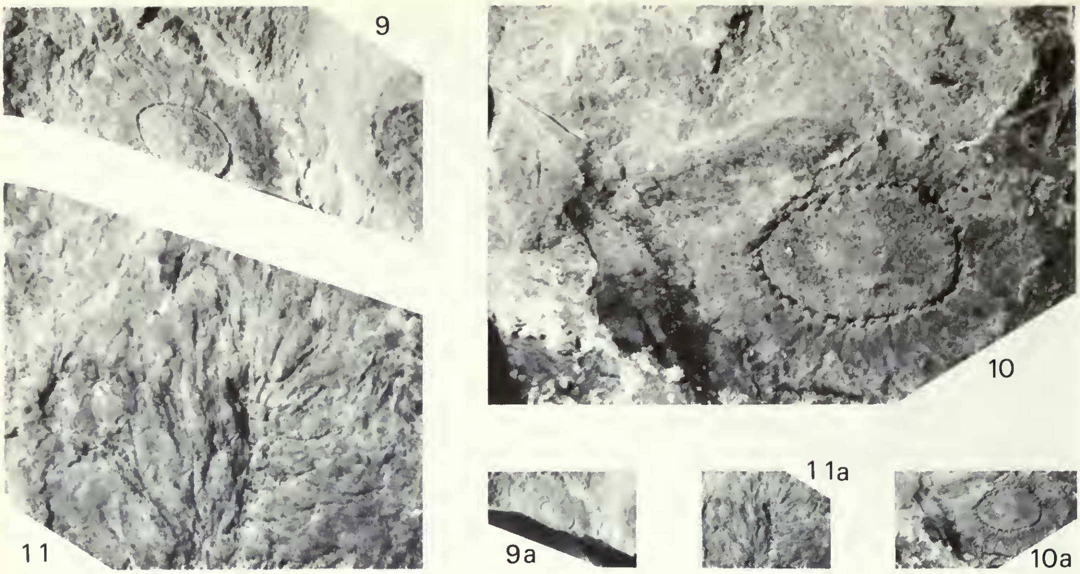
Lepidostrobophyllum lanceolatum (Lindley & Hutton) Bell

Fig. 15

1831 *Lepidophyllum lanceolatum* Lindley & Hutton: 28; pl. 7, figs 3–4.
1848 *Lepidostrobus lanceolatus* (Lindley & Hutton) Göppert *in* Bronn: 632.
1938 *Lepidostrobophyllum lanceolatum* (Lindley & Hutton) Bell: 97; pl. 98, figs 10–11.
1966 *Lepidostrobus lanceolatus* (Lindley & Hutton); Crookall: 503; pl. 99, figs 4–5 (q.v. for synonymy).

Description. Most of the specimens found were of isolated sporophylls. One part-whorl was seen (cf. Crookall 1966: pl. 99, fig. 4) but it was on a thin sliver of rock which proved impossible to extract. The sporophyll blade is 20–25 mm long and 6 mm wide. It is lanceolate with a pointed apex, and is widest $\frac{1}{2}$ to $\frac{2}{3}$ of the way along its length. A single vein *c.* 1 mm wide extends along the long axis of the blade. A fine line is often superimposed along the centre of the vein (cf. Boulter 1968: text fig. 3). The pedicle is ovoid, 4–9 mm long and 3–4 mm wide. Folds are often present along the margins of the pedicle.

Remarks. As pointed out by Crookall (1966: 506), the separation of species based on isolated sporophylls is somewhat arbitary. The Edgehills specimens are of the form known as *L.*



Figs 9–10 *Archaeocalamites radiatus*, nodal diaphragms. Figs 9, 9a, V.61747. Figs. 10, 10a, V.61748. Figs 9, 10, × 3. Figs. 9a, 10a, × 1.

Fig. 11 ?*Tomiodendron variabilis*, slender leafy shoot possibly belonging to this species, V.61752. × 3; Fig. 11a, × 1.

lanceolatum (Lindley & Hutton), which has been widely recorded from both Mississippian and Pennsylvanian floras. However, it is most unlikely that all of the recorded examples of this sporophyll-type belonged to the same natural species. The only other type of sporophyll which resembles the specimens found at Edgehills is known as *L. intermedium* (Lindley & Hutton), but this usually has a more linear blade.

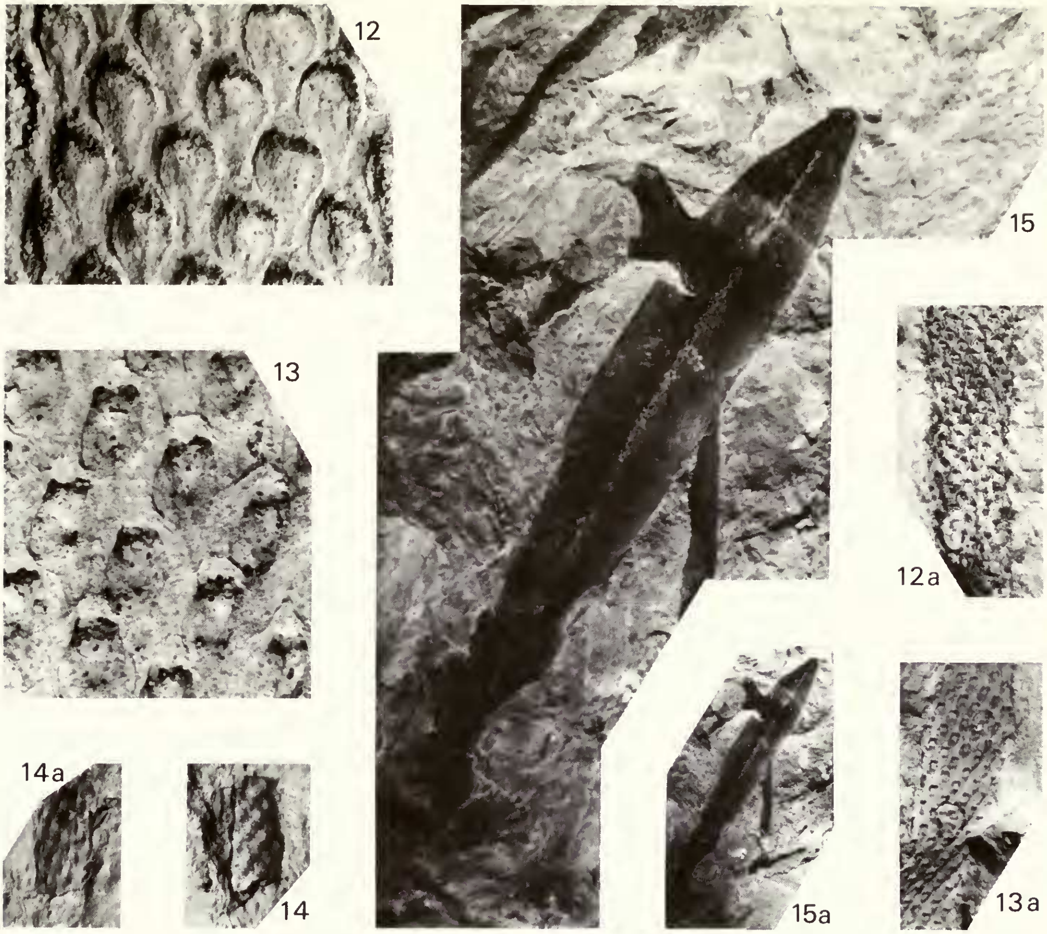
It is tempting to link these sporophylls with only the lycopod stems found at Edgehills: *Tomiodendron variabilis* (Lele & Walton); see below. However, in the only other locality to have yielded this type of stem (Puddlebrook Quarry, Forest of Dean) such lanceolate sporophylls are absent (Lele & Walton 1962). Neither have they been reported in association with other species of *Tomiodendron* (e.g. Gorelova 1978). Since the Edgehills assemblage is clearly allochthonous, any statement as to the affinities of these sporophylls based only on association would be unwise.

Form-genus ***TOMIODENDRON*** Radczenko 1956, emend. Meyen 1972

Tomiodendron variabilis (Lele & Walton) Thomas & Purdy
Figs 12–13, ? Figs 11, 14

1962 *Scutellocladus variabilis* Lele & Walton: 138; pl. 19, figs 1–6.
1982 *Tomiodendron variabilis* (Lele & Walton) Thomas & Purdy: 134; figs 4–14.

Description. Two specimens of stems were found showing leaf cushions, both of which are 12 mm wide. One is 35 mm long and the other 45 mm long. The leaf cushions are 3 mm long and 1·5 mm wide, and vary from oval (Fig. 13) to bulbously rhomboidal (Fig. 12) in shape. Leaves are attached to the upper part of the cushion, and appear to be persistent. Some leaf cushions have a central depression, probably owing to an infrafoliar bladder, but the preservation is too poor to be certain. The more oval leaf cushions have a small downwards-projecting protuberance, which is probably evidence of a ligule pit (Fig. 13). The leaf cushions are arranged in a steep spiral.



Figs 12–13 *Tomiodendron variabilis.* Fig. 12a, typical stem, V.61753, × 1. Fig. 12, close-up of Fig. 12a, showing rhomboidal form of leaf cushions. × 6. Fig. 13a, typical stem, but a little distorted, V.61754. × 1. Fig. 13, close-up of Fig. 13a, showing leaf cushions with more rounded shape. × 6.
Figs 14, 14a ?*Tomiodendron variabilis*, part and counterpart of decorticated stem, V.61755. × 1.
Fig. 15 *Lepidostrobophyllum lanceolatum*, isolated sporophyll, V.61756. × 3; Fig. 16a × 1.

The specimen shown in Fig. 11 shows a slender leafy stem 1·5 mm wide. It bears spirally arranged leaves, which are narrow and linear, 7–9 mm long and 1 mm wide. This is probably the distal part of a stem of *T. variabilis* (Lele & Walton).

Figs 14 and 14a are part and counterpart of a decorticated stem probably belonging to *T. variabilis* (Lele & Walton), but without evidence of the outer surface of the stem the identification cannot be confirmed.

Remarks. Compared with the types of the species (Lele & Walton 1962), the Edgehills specimens seem to have more prominent leaf cushions. However, Thomas & Purdy (1982) have shown that this feature varies considerably in appearance in *T. variabilis* (Lele & Walton), depending on where the specimen splits, and the Edgehills specimens easily fit within this range of variation. The persistent leaves, prominent ligule pit and small infrafoliar bladder are all characteristic features of *T. variabilis* (Lele & Walton). This is only the second locality from where it has been recorded.

Division **PTERIDOSPERMOPHYTA?**

Naked axes

DESCRIPTION. Several naked axes with lateral branching occur in this flora. They are *c.* 3 mm wide. No specimen has more than one branch and so the interbranch distance is unknown. There are also larger stems *c.* 12 mm wide, with a wrinkled surface. No foliage was found attached to these stems.

REMARKS. Without foliage, it is impossible to be sure what plant-type bore these stems. However, the Viséan age indicated by the rest of the flora tends to point to pteridosperm rather than fern affinities. The larger wrinkled stems are rather similar to the 'Spindelreste von Pteridophylla' of Nathorst (1914: pl. 1, figs 3–5). Lyginopterid pteridosperm stems have comparable surface markings owing to sclerotic plates in the cortex.

Discussion

The flora consists almost entirely of equisetes and lycopods, with only rare examples of ?pteridosperm axes. It is clearly an allochthonous assemblage, the plants being fragmentary and well sorted. This sorting is well demonstrated by the proportions of the different organs found for the different group of plants.

	stems	foliage	fructifications
equisetes	a	—	—
lycopods	r	r	a
?pteridosperms	r	—	—

a = abundant r = rare — = absent

Such equisete/lycopod dominated assemblages have been referred to as 'flöznahe' (Havlena 1961), indicating that they grew in or near the coal-forming swamps. In the Westphalian, they have been reported from mudstones interpreted as prodelta lacustrine deposits (Scott 1978).

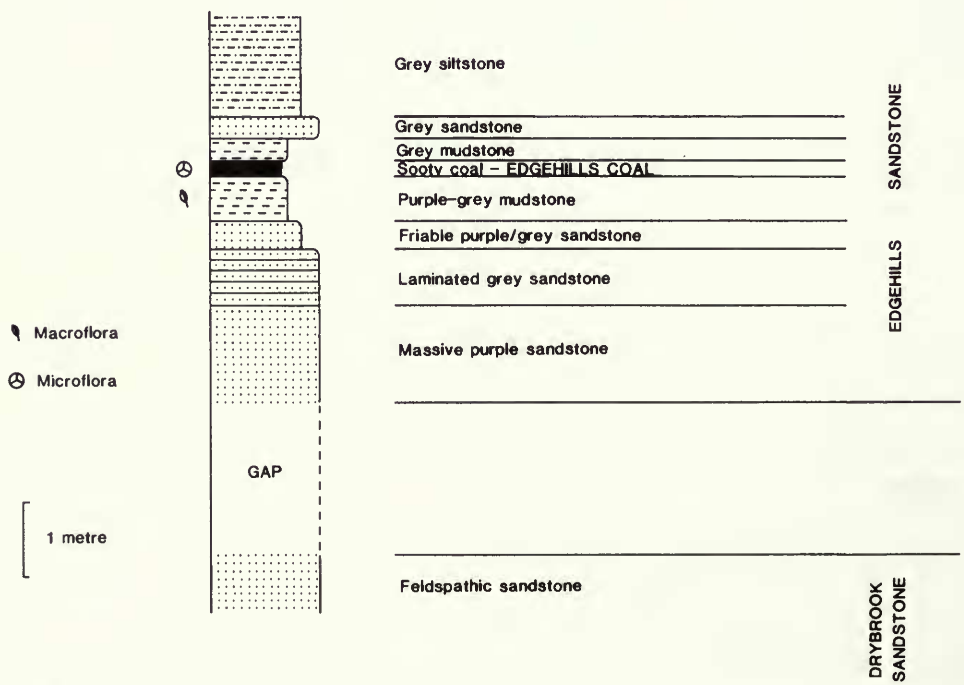


Fig. 16 Stratigraphical section through the Edgehills Sandstone, as seen in March 1983.

Under normal circumstances, such a flora would not be used for biostratigraphy. Assemblages dominated by foliage, particularly of ferns, pteridosperms and equisetes are usually preferred for such work. However, it is the only evidence available for the Edgehills Sandstone (other than the palynology) and so it is important to analyse whatever it can tell us.

Crookall (1932) stated that *Archaeocalamites radiatus* (Brongniart) occurs in the Oil Shale Group and Carboniferous Limestone 'Series' of Scotland, suggesting a stratigraphical range from about the late Asbian to the Arnsbergian. Elsewhere in western and central Europe, the most comprehensive floral records for strata of this age are from Moravia in Czechoslovakia (e.g. Hartung & Patteisky 1960, Purkyňová 1977), where *A. radiatus* (Brongniart) extends up to the Nanetta Marine Band (middle Pendleian). In the Soviet Union it is stated to have a latest occurrence in the upper Serpukhovian, below the D_4 limestone (Novik 1968, Aisenverg *et al.* 1979) which correlates with about the middle Arnsbergian. North American records show that it extends up to the top of the Mississippian (Pfefferkorn & Gillespie 1982), which is probably also equivalent to a level somewhere in the Arnsbergian (Manger & Saunders 1982). Recently, Tidwell (*in* Webster *et al.* 1984) has stated that it is known to extend up into the Westphalian A, but does not give the evidence on which this is based. Certainly all the published records suggest that *A. radiatus* (Brongniart) does not range above the Arnsbergian or its correlatives (cf. Wagner 1984: 114).

The *Lepidostrobophyllum lanceolatum* (Lindley & Hutton) type of sporophyll has a long stratigraphical range. In Britain it has been recorded from the lower Mississippian Cementstone Group (Crookall 1932) through to the Westphalian D (Dix 1934). It is thus of little biostratigraphical value.

Tomiodendron variabilis (Lele & Walton) is only known from one other locality: Puddlebrook Quarry in the Forest of Dean. Here it is found in the Drybrook Sandstone, which is probably of middle Asbian age (Sullivan 1964, George *et al.* 1976). *Tomiodendron* is principally a Mississippian form-genus (Meyen 1976, Gorelova 1978).

The macroflora clearly indicates an early Carboniferous (i.e. Mississippian) age for the Edgehills Sandstone. This agrees with the field evidence, there being no evident non-sequence between the Edgehills and Drybrook sandstones. However, it is in marked contrast to the Westphalian A age suggested by Sullivan (1964) and Spinner (1984), based on palynological evidence. Sullivan based his conclusions on an assemblage of 43 microspore form-species. Several of the species which he regarded as supporting a Westphalian A age have since been reported at much lower horizons in the Arnsbergian and Pendleian, viz. *Cirratriradites saturni* (Ibrahim), *Crassispora kosankei* (Potonié & Kremp) and *Apiculatisporis variorcorneus* Sullivan (see Owens *et al.* 1978, Owens 1982, Coquel *et al.* 1984, Owens *et al.* 1984). It is also noticeable that several of the species usually associated with lower Westphalian A microspore assemblages were not reported from the Edgehills Sandstone, in particular the group allied to *Triquitrites sinani* Artuz (Owens *et al.* 1978), and *Densosporites annulatus* (Loose) (Smith & Butterworth 1967). On the other hand, there are aspects of the assemblage described by Sullivan which support a lower Westphalian A designation, particularly the *Florinites* and *Raistrickia* components. It would seem that the evidence provided by Sullivan's assemblage is rather equivocal for assigning an age to the Edgehills Coal. In order to obtain additional palynological data, the present author collected another specimen of the coal, as well as taking examples of the mudstones immediately underlying and overlying it. E. Spinner (University of Sheffield) kindly processed this material, but only found very poorly preserved spores, in marked contrast to the abundant and beautifully preserved specimens described by Sullivan. The problem clearly requires further investigation, perhaps using fresher samples than were available during this study.

The megaspores described by Spinner (1984) from the Edgehills Coal do not clarify the issue. He found that they had the same general character to those found in the Drybrook Sandstone, and that there is no evidence of lageniculate megaspores, as would be expected in a Westphalian A assemblage. However, the dominant component, *Cystosporites varius* (Wicher), is so far unrecorded from below the Westphalian. The presence of *Triangulatisporites regalis* (Ibrahim) and *Tuberculatisporites apiculatus* (Ibrahim) also seem to support a Westphalian age, although Spinner points out that there are a number of taxonomic difficulties with this group of megaspores.

In contrast to the above biostratigraphical evidence of the spores, the macrofloral evidence seems unequivocal. The general pattern of geological development of the area also seems to support an Asbian rather than a Westphalian A age for the Edgehills Sandstone. During the Namurian and most of the Westphalian, the Forest of Dean was part of an active area of uplift which supplied sediment to both the South Wales and Bristol/Somerset basins. Sullivan argued that there must have been a pause in this uplift during the early Westphalian A, allowing sediment to spread out eastwards from the South Wales basin. There is indeed some evidence that tectonic activity in the area was reduced during the early Westphalian A, Bluck (1961) showing that there was little coarse sediment derived from the east coming into the South Wales basin at that time. However, channel vectors determined by Bluck continue to show a predominantly westerly current flow in the eastern part of the South Wales basin. Furthermore, the isopachyte map given by Leitch *et al.* (1958) for the basal Westphalian A strata in south Wales shows a marked thinning of the sequence towards the east. Although perhaps not as dynamically active as at other times during the Carboniferous, the Forest of Dean was still an upland area during the early Westphalian A and is thus unlikely to have been the site of any major sedimentation at this time. If the existence of Westphalian A strata in the Forest of Dean were eventually proved, then they would have to be localized upland deposits, unconnected with the major basinal systems in south Wales and Avon–Somerset. However, the available evidence suggests that the Edgehills Sandstone is probably Asbian in age, and is not a relict of a period of Westphalian sedimentation in the Forest of Dean.

Acknowledgements

This paper is dedicated to the memory of Miss Morag Jones, who helped the author in the fieldwork at Edgehills Quarry, a few months before her fatal road accident in north Africa. The work is a byproduct of a survey of British Westphalian sites, carried out for the Nature Conservancy Council, Geological Conservation Review Unit, at the invitation of Dr G. P. Black. Thanks go to the staff of the unit for help with the work, especially to Mr P. Cann for library assistance. The palynological problems which arose from the study have been discussed with Dr M. A. Butterworth, Dr G. Clayton, Mr S. Jusypiw, Dr J. B. Richardson and Dr W. A. Wimbledon who are thanked for their advice. Finally, I would like to thank Dr B. A. Thomas, Dr H. J. Sullivan, Dr E. Spinner and Mr C. H. Shute for critically reading the manuscript and making numerous helpful suggestions.

References

Aisenverg, D. E., Brazhnikova, N. E., Vassilyuk, N. P., Reitlinger, E. A., Fomina, E. V. & Einor, O. L. 1979. The Serpukhovian Stage of the Lower Carboniferous of the U.S.S.R. *In* Wagner, R. H., Higgins, A. C. & Meyen, S. V. (eds), *The Carboniferous of the U.S.S.R.*: 43–59, pls 2–6. Leeds (Yorkshire Geological Society, Occasional Publication **4**).

Bell, W. A. 1938. Fossil flora of the Sydney Coalfield. *Mem. geol. Surv. Brch Can.*, Ottawa, **215:** 1–334, pls 1–107.

Bluck, B. J. (1961). *The sedimentary history of the rocks between the horizons of* G. subcrenatum *and the Garw Coal in the South Wales Coalfield.* Ph.D. thesis, Univ. of Wales (unpubl.).

Boulter, M. C. 1968. A species of compressed lycopod sporophyll from the Upper Coal Measures of Somerset. *Palaeontology*, London, **11:** 445–457, pls 83–84.

Brongniart, A. 1828. *Histoire des végétaux fossiles*, **1:** 81–136, pls 9bis, 10, 12, 15, 19–27. Paris.

Bronn, H. G. 1848. *Index palaeontologicus, oder übersicht der bis jetzt bekannten fossilien organismen.* 1384 pp. Stuttgart.

Coquel, R., Loboziak, S., Owens, B. & Teteriuk, V. K. 1984. Comparison entre la distribution des principales microspores-guide du Namurien et du Westphalien en Europe occidentale et dans le bassin Donetz (URSS). *C. r. 9e Congr. Int. Strat. Géol. Carbon.*, Washington & Urbana, **2:** 443–446.

Crookall, R. 1932. Stratigraphical distribution of British Lower Carboniferous plants. *Mem. geol. Surv. Summ. Prog.*, London, **1931** (2): 70–104.

—— 1964–66. Fossil plants of the Carboniferous rocks of Great Britain. Second section, Part 3. *Mem. geol. Surv. Gt Br. Palaeont.*, London, **4:** 217–354, pls 59–81 (1964). Part 4. *loc cit.*: 355–572, pls 82–106 (1966).

Dix, E. 1934. The sequence of floras in the Upper Carboniferous, with special reference to South Wales. *Trans. R. Soc. Edinb.*, **57:** 789–838.

George, T. N., Johnson, G. A. L., Mitchell, M., Prentice, J. E., Ramsbottom, W. H. C., Sevastopulo, G. D. & Wilson, R. B. 1976. A correlation of the Dinantian rocks in the British Isles. *Spec. Rep. geol. Soc. Lond.*, **7.** 87 pp.

Gorelova, S. G. 1978. The flora and stratigraphy of the coal-bearing Carboniferous of middle Siberia. *Palaeontographica*, Stuttgart, (B) **165:** 53–77, 4 textfigs, 14 pls.

Hartung, W. 1938. Flora und Alterstellung des Karbons von Hainichen-Ebersdorf und Borna bei Chemnitz. *Abh. sächs. geol. Landesants*, Leipzig, **18:** 5–140, pls 1–19.

—— **& Patteisky, K.** 1960. Die Flora der Goniatiten-Zonen in Visé und Namur des ostsudetischen Karbons. *C. r. 4e Congr. Int. Strat. Géol. Carbon.*, Heerlen, **1:** 247–262.

Havlena, V. 1961. Die flöznahe und flözfremde Flora des Oberschlesischen Namurs A und B. *Palaeontographica*, Stuttgart, (B) **108:** 22–38, 2 textfigs, 2 tables, pls 6–9.

Hirmer, M. 1927. *Handbuch der Paläobotanik*, **1.** 708 pp., 816 figs. Berlin & Munich.

Leistikow, K. U. 1959. *Archaeocalamites* und Archaeocalamitaceae. *Taxon*, Utrecht, **8:** 48–52.

Leitch, D., Owen, T. R. & Jones, D. G. 1958. The basal Coal Measures of the South Wales Coalfield from Llandybie to Brynmawr. *Q. Jl geol. Soc. Lond.*, **93:** 461–486.

Lele, K. M. & Walton, J. 1962. Fossil flora of the Drybrook Sandstone in the Forest of Dean, Gloucestershire. *Bull. Br. Mus. nat. Hist.*, London (Geol.) **7** (4): 137–152, pls 19–23.

Lindley, J. & Hutton, W. 1831. *The fossil flora of Great Britain: or figures and descriptions of the vegetable remains found in a fossil state in this country.* **1** (1): 1–48, pls 1–14. London.

Manger, W. L. & Saunders, W. B. 1982. An ammonoid based middle Carboniferous boundary. *In* Ramsbottom, W. H. C., Saunders, W. B. & Owens, B. (eds), *Biostratigraphic data for a mid-Carboniferous boundary*: 95–100. Leeds.

Meyen, S. V. 1972. Are there ligula and parichnos in Angara Carboniferous lepidophytes? *Rev. Palaeobot. Palynol.*, Amsterdam, **14** (1/2): 149–157, 5 textfigs, 1 pl.

—— 1976. Carboniferous and Permian lepidophytes of Angaraland. *Palaeontographica*, Stuttgart, (B) **157** (5/6): 122–157, 33 textfigs, 12 pls.

Nathorst, A. G. 1914. *Nachträge zur paläozoischen Flora Spitzbergens.* 110 pp., 15 pls. Stockholm.

Novik, K. O. 1968. [*Flora from the lower Carboniferous of the Donets Basin and its western continuation.*] 234 pp., 51 pls. Kiev. [In Russian].

Owens, B. 1982. Palynological zonation of mid-Namurian strata in northern England. *In* Ramsbottom, W. H. C., Saunders, W. B. & Owens, B. (eds), *Biostratigraphic data for a mid-Carboniferous boundary*: 22–26. Leeds.

——, **Loboziak, S. & Coquel, R.** 1984. Late Mississippian–Early Pennsylvanian miospore assemblages from northern Arkansas. *C. r. 9e Congr. Int. Strat. Géol. Carbon.*, Washington & Urbana, **2:** 377–384, 1 pl.

——, —— **& Teteriuk, V. K.** 1978. Palynological subdivision of the Dinantian to Westphalian deposits of northwest Europe and the Donetz Basin of the U.S.S.R. *Palynology*, Austin, Texas, **2:** 69–91.

Pfefferkorn, H. W. & Gillespie, W. H. 1982. Plant megafossils near the Mississippian–Pennsylvanian boundary in the Pennsylvanian System stratotype, West Virginia/Virginia. *In* Ramsbottom, W. H. C., Saunders, W. B. & Owens, B. (eds), *Biostratigraphic data for a mid-Carboniferous boundary*: 128–133. Leeds.

Purkyňová, E. 1977. Namurian flora of the Moravian part of the Upper Silesian Coal Basin. *In* Holub, V. M. & Wagner, R. H. (eds), *Symposium on Carboniferous stratigraphy*: 289–303, 4 pls. Prague.

Radczenko, G. P. 1956. Genera *Siberiodendron, Tomiodendron, Abacodendron. Trudÿ vses. Nauchno-issled. geol. Inst.*, Leningrad, (n.s., palaeont.) **12:** 194–203. [In Russian].

Schimper, W. P. 1862. Terrain de transition Vosges. *Mém. Soc. Sci. nat. Strasbourg*, **5:** 309–348.

Schlotheim, E. F. von 1820. *Die Petrefactenkunde auf ihrem jetztigen Standpunkte durch die Beschreibung seiner Sammlung versteinerter und fossiler Überreste des Thier- und Pflanzenreichs der Vorwelt erläutert.* 437 pp., 15 pls. Gotha.

Scott, A. C. 1978. Sedimentological and ecological control of Westphalian B plant assemblages in West Yorkshire. *Proc. Yorks. geol. Soc.*, Leeds, **41:** 461–508, pls 25–29.

Smith, A. H. V. & Butterworth, M. A. 1967. Miospores in the coal seams of the Carboniferous of Great Britain. *Spec. Pap. Palaeont.*, London, **1.** 324 pp., 27 pls.

Spinner, E. 1984. The occurrence and distribution of megaspores in the Drybrook Sandstone and associated measures of the Forest of Dean, Gloucestershire, England. *J. Micropalaeont.*, London, **3**: 37–41, 1 pl.

Stur, D. 1875. Die Culm-Flora des mahrisch-schlesischen Dachschiefers. *Abh. K.-K. geol. Reichanst.*, Vienna, **8**. 106 pp., 17 pls.

Sullivan, H. J. 1964. Miospores from the Drybrook Sandstone and associated measures in the Forest of Dean, Gloucestershire. *Palaeontology*, London, **7**: 351–392.

Thomas, B. A. & Purdy, H. M. 1982. Additional fossil plants from the Drybrook Sandstone, Forest of Dean, Gloucestershire. *Bull. Br. Mus. nat. Hist.*, London, (Geol.) **36** (2): 131–142, 14 figs, 1 table.

Wagner, R. H. 1984. Megafloral zones of the Carboniferous. *C. r. 9e Congr. Int. Strat. Géol. Carbon.*, Washington & Urbana, **2**: 109–134, 3 tables.

Walton, J. 1949. On some Lower Carboniferous equisetineae from the Clyde area. *Trans. R. Soc. Edinb.*, **61**: 729–736, 2 textfigs, 2 pls.

Webster, G. D., Brenckle, P., Gordon, M. jr, Lane, H. R., Langenheim, R. L. jr, Sanderson, G. A. & Tidwell, W. D. 1984. The Mississippian–Pennsylvanian boundary in the Eastern Great Basin. *C. r. 9e Congr. Int. Strat. Géol. Carbon.*, Washington & Urbana, **2**: 406–418, 3 textfigs.

Zeiller, R. 1879. Végétaux fossiles du terrain houiller. *Explic. Carte géol. France*, Paris, **4** (2): 1–185, Atlas pls 159–176.